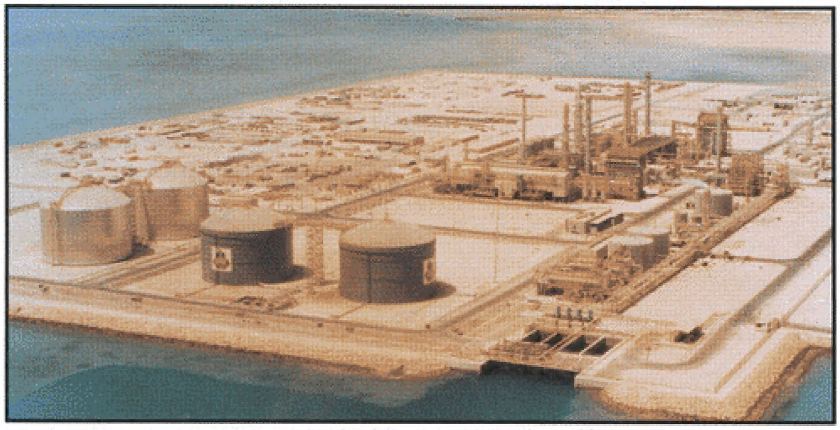
Petrochemical company uses online information to keep critical machine running



Gulf Petrochemical Industries Company, Bahrain

by Ron Bosmans
Principal Engineer
Bently Nevada Corporation

The Gulf Petrochemical Industries Company (GPIC), a petrochemical company located in Bahrain, recently purchased a Bently Nevada Engineer Assist™ system and installed it on a computer in their Mechanical Maintenance Section. The machine train consists of a mechanical drive steam turbine, two barrel compressors, and a circulation compressor. An analysis of this machine train was conducted on December 11, 1994.

All the critical equipment in the plant is equipped with the following Bently Nevada hardware and software: proximity probes, 3300 Vibration Monitors, and the Transient Data Manager® 2 (TDM2) data-gathering computer system.

The TDM2 Software includes an application called an Acceptance Region. The Acceptance Region is used to define a range of "normal" values of 1X and 2X amplitude and phase vectors for each measurement location on a machine. Acceptance Regions are displayed in polar format (Figure 2). The Acceptance Region's limits were established by GPIC personnel, based on machine data collected over a period of four weeks, when the machine was considered to be in good working condition. Significant changes in 1X amplitude or phase that place the vector outside the Acceptance Region indicate aberrant machine behavior.

The TDM2 trend files revealed that the changes in the 1X vectors began to occur during the second two weeks in September 1994. Plant personnel were aware that these changes were occurring over this period and were concerned about continued operation of the machine.►

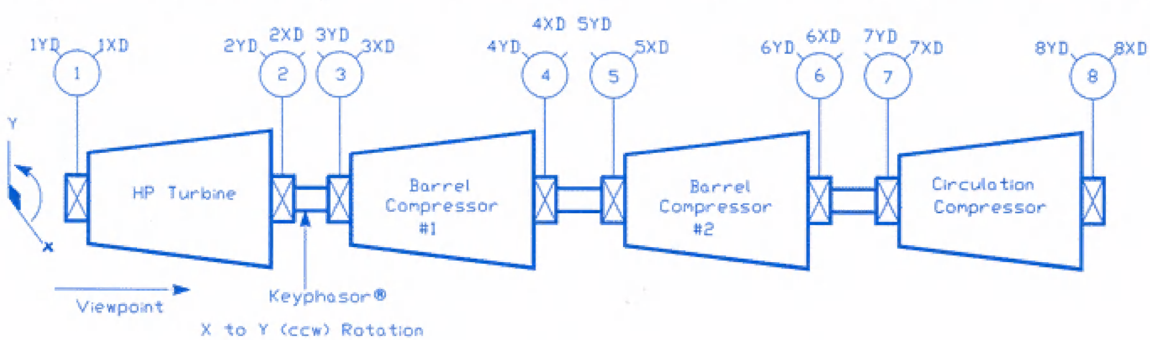


Figure 1
Makeup gas compressor train

The Engineer Assist audit, based on vibration data from the TDM2 System, indicated several explanations for this type of behavior. They include changes in the balance state of the rotor and a rotor crack that is propagating. A rotor crack possibility could be confirmed if recent startup or shutdown data were available. However, the only shutdown data available was from a shutdown in October 1993. The data had been acquired with an ADRE® (Advanced Diagnostics for Rotating Equipment) for Windows System; this was old data, but it was still considered useful. The data revealed that the compressor was operating at a speed just above the second balance resonance (critical speed). See Figures 3 and 4. A small increase or decrease in the resonance frequency would explain the observed 1X amplitude and phase change.The equation that governs the frequency of a mechanical resonance is:

$$\omega_{RES} = \sqrt{\frac{K}{M}}$$

Where:

ω_{RES} = Resonance frequency (rad/s)

K = Modal (effective) System Stiffness (lb / in)

M = Modal (effective) Rotor Mass (lb • s² / in)

For a mechanical resonance frequency to change, the rotor mass, the system stiffness, or both, must change. The rotor's mass is essentially constant. Therefore, the system stiffness must have changed. Had the stiffness increased or decreased ?

Engineer Assist reported that the 1X phase changes were categorized as "leading" phase angle changes. This would indicate that the second balance resonance frequency, which was initially below operating speed, had increased and is now above operating speed. System stiffness for that mode must have increased. Where ? How ?

This compressor is equipped with floating bushing shaft end seals. This type of seal is supplied with seal oil that is pressurized and maintained at 34.5 to 103.4 kPa (5 to 15 psi) above the internal gas pressure of the compressor. The design diametral clearance of the seal is 0.09 mm (3.6 mils). The seals contribute to the system stiffness. Although they are not designed to be rotor supports, they may act as partial bearings. If the diametral clearance is reduced, the system stiffness will increase. A trend review of the seal oil flow through the seals from September through December indicated that flow had dropped to 25% of design flow.

During the last overhaul of this compressor, the rotor was replaced with the spare rotor. Inspection of the removed rotor revealed a buildup of a substance on the rotor in the area of the floating

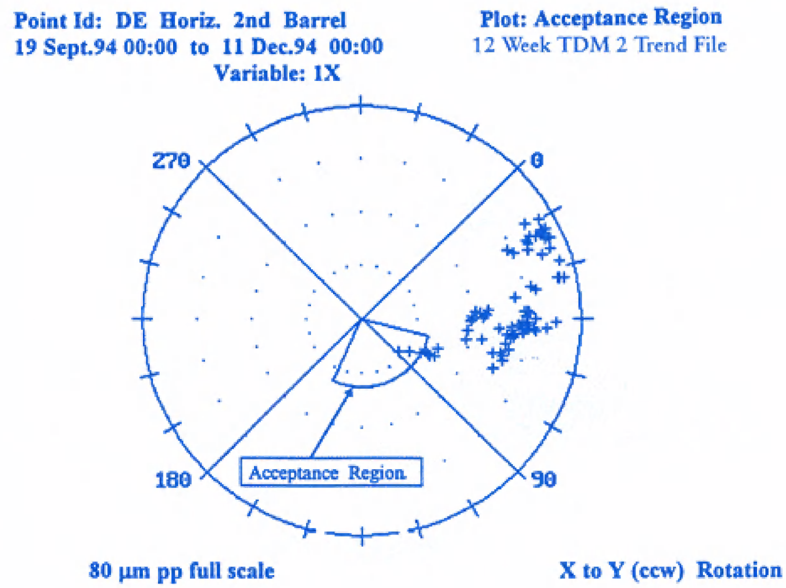


Figure 2
Acceptance Region plot

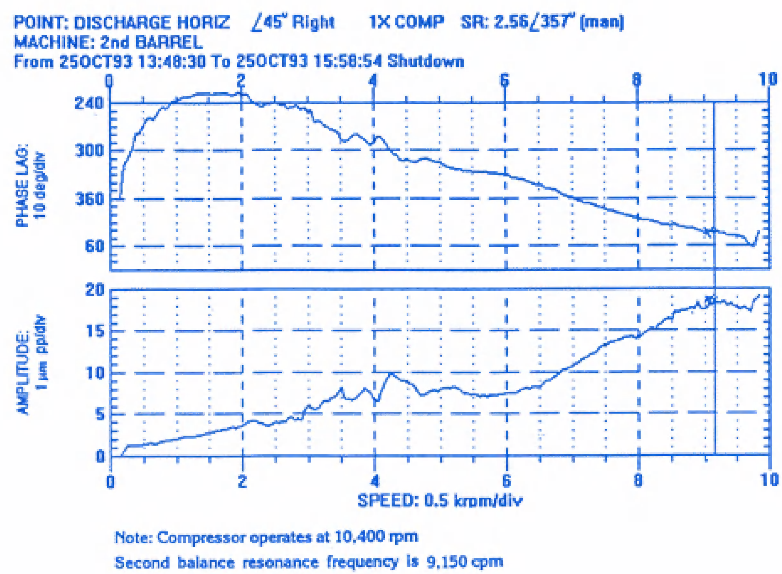


Figure 3
Bode plot of October 1993 shutdown

bushing seals. If the current rotor had the same buildup, it would be evidence that the system stiffness had increased.

Preparations were made to shut down the machine train on January 14, 1995. To safely manage the machine until then, we defined a new Acceptance Region on December 15. If the new Acceptance Region were violated, the machine would be shut down immediately. The rotor's response (Figures 5 and 6) during shutdown indicates that, at the time of the shutdown, the second balance resonance frequency was above running speed. This data confirms the suspected change in system stiffness. Upon removal of the rotor, the seal area was inspected. The substance found on the rotor was identical to that found on the previous rotor. The diametral clearance in the seal had been reduced to 0.01 mm (0.4 mil).

Conclusion

Three Bently Nevada products contributed to provide actionable information and to assist plant management and maintenance pesonnel to manage their machinery. The TDM2 System revealed the time history of the changes in the 1X vectors. A second Acceptance Region was defined on 15 December to carefully monitor any further degradation. Violation of the new Acceptance Region would be cause for an immediate shutdown. Speed and the flow rate were reduced to control the level of the increasing 1X vibration. The ADRE® for Windows data from the previous shutdown was instrumental in revealing the location of the second balance resonance.

This information allowed plant management to manage their machinery and minimize the possibility of an unplanned forced outage, which would have cost them approximately $2.5 million in production. The planned shutdown permitted Maintenance to prepare the required personnel and spare parts. Since the outage was planned and Maintenance understood the nature of the problem, they were able to quickly change the rotors for spares and get back online. The total outage time was five days. ■

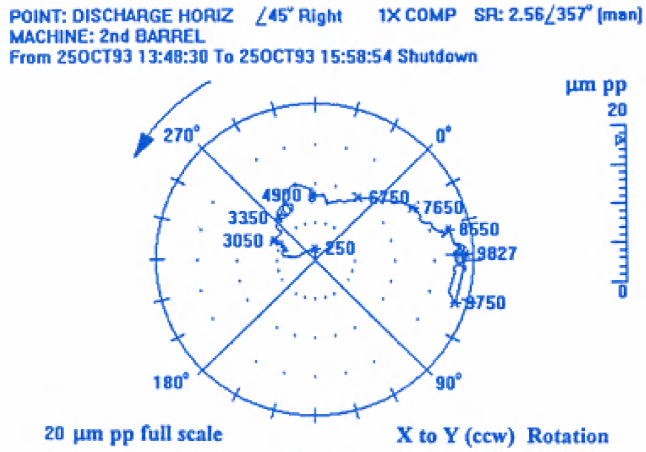


Figure 4
Polar plot of October 1993 shutdown

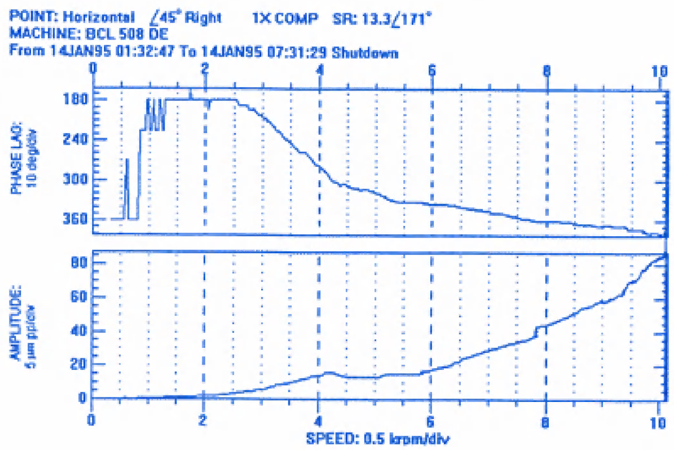


Figure 5
Bode plot of January 1995 shutdown.

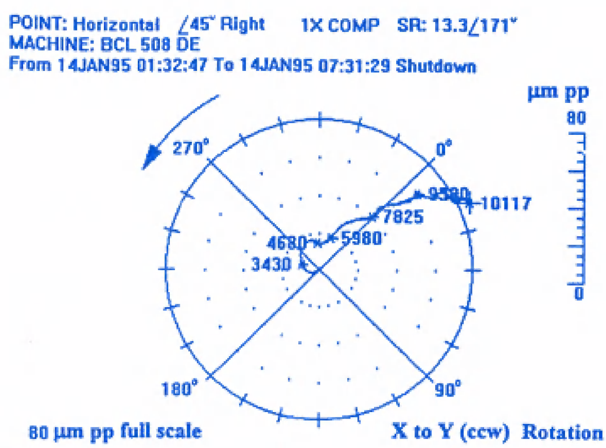


Figure 6
Polar plot of January 1995 shutdown.